Adaptive Learning Systems for Students with Intellectual and Developmental Disabilities

Bipin Sule[1], Vidya V. Deshmukh[2], Rahul Sonavale[3], Tanveer Ahmad Wani[4], Hari Hara Subramanyan P.V.[5], Ugiljon Qushnazarova[6], Marhabo Matniyozova[7]

[1]Sr. Professor, Department of DESH, Vishwakarma Institute of Technology, Pune, Maharashtra, 411037
email ID : bipin.sule@vit.edu

[2]Department of Electronics and Telecommunication Engineering, AISSMS College of Engineering, Pune, Maharashtra, India. vvdeshmukh@aissmscoe.com

[3](Corresponding Author), Krishna Institute of Science and Technology,
Krishna Vishwa Vidyapeeth "Deemed to be University", Taluka-Karad, Dist-Satara, Pin-415 539, Maharashtra, India
rahulsonavale777@gmail.com

[4]School of Sciences,Noida International University,Uttar Pradesh 203201,India. tanveer.ahmad@niu.edu.in

[5]Associate Professor , Meenakshi College of Physiotherapy, Meenakshi Academy of Higher Education and Research,Chennai. Tamilnadu. hari@maher.ac.in

[6]Department of Pedagogy and psychology, Urgench state university, Urgench. Uzbekistan.
ogiljon@urdu.uz
0009-0001-8767-6921

[7]Affiliation: Department of Psychology and Medicine, Mamun university, Khiva Uzbekistan
Email: matniyozovamarhabo@gmail.com
https://orcid.org/0009-0007-8374-0977 """

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ABSTRACT:
Adaptive learning systems have become one of the promising applications of improving the inclusive education, especially among students with Intellectual and Developmental Disabilities (IDD). These students tend to encounter difficulties with cognitive processing, interacting and learning in conventional learning contexts. This paper suggests a smart adaptive learning model that combines artificial intelligence, assistive technology, and inclusive pedagogy, to deliver customized and accessible learning experiences. The framework will be developed based on a modular architecture that includes profiling of learners, data collection, adaptive content delivery, supportive assistance and feedback systems. The program employs machine learning algorithms to process the behavior of learners and modify the instructional materials as per the needs, preferences and performance of the learners dynamically. Both the concept of multimodal content delivery and the Universal Design of Learning (UDL) can guarantee the access to the educational resources and their flexibility, allowing learners to engage with

the educational materials in varying manners. Also, the usability of students with communication and motor disabilities is improved by the presence of assistive technology (text-to-speech, speech-to-text and Augmentative and Alternative Communication (AAC)). Experimental analysis reveals that the adaptive learning system developed is much more effective in terms of learning outcomes, engagement, and effectiveness in personalization as opposed to conventional learning methods. The outcomes show an increased accuracy, comprehending the concepts better, higher rates of accomplishing tasks and a decrease in the level of frustration among learners. The study comparing the adaptive model with other models through the use of graphical representations further support its superiority in various aspects such as performance, usability and accessibility. The research concludes that adaptive learning systems will be instrumental in changing the concept of inclusive education through offering customized, smart, and supportive learning systems.

Keywords: Adaptive Learning Systems; Intellectual and Developmental Disabilities (IDD); Inclusive Education; Artificial Intelligence; Personalized Learning; Assistive Technologies; Universal Design for Learning (UDL); Learning Analytics; Educational Technology; Human-Centered Design.

I. Introduction

Adaptive learning systems have become a new face changer in state of the art education whereby personalized instruction is based on the individual needs, abilities and learning pace of individual learners. These systems are based on the principles of artificial intelligence, machine learning, and data analytics that are dynamically used to adapt instructional content, assessment strategy, and feedback mechanisms. Digital technologies such as mobile applications and intelligent systems have shown more and more potential in the context of inclusive education to support people with cognitive and developmental challenges in terms of accessibility, usability, and engagement (Huang et al., 2025; Van Wingerden et al., 2023).

Intellectual and Developmental Disabilities is a spectrum of disorders, where they have restrictions in cognitive functioning, adaptive functioning, communication and social interaction. When placed in a normal classroom environment, students with IDD are likely to face major difficulties because the teaching methods used might not cater to the differing cognitive and behavioral requirements. Studies also show that assistive communication interventions like augmentative and alternative communication (AAC) are essential in facilitating successful communication and engagement among autistic people (Donaldson et al., 2021). Also, social communication and emotional regulation have been reported to be enhanced by technology-based interventions, such as tablet-based learning tools, especially in students with autism, whether in special or mainstream schools (Achtypi and Papoudi, 2024).

Adaptive learning systems are in a unique position to tackle these issues by integrating intelligent technologies with the design-based around the learner. The systems use the data of learners to create individual learning trajectories, constantly adjusting the learning content depending on performance and interest. Cognitive and behavioral research indicates that individualized and structured

interventions can greatly improve emotional and cognitive outcomes in children and especially those with anxiety and developmental disorders (Alemdar & Karaca, 2025). Moreover, adaptive and assistive digital ecosystems have been demonstrated to enhance well-being, independence, and everyday functioning of people with disabilities due to the integration of intelligent personal assistants and interactive technology (Van Wingerden et al., 2023). Although these developments are in place, there are still a number of issues in the successful implementation of adaptive learning systems to students with IDD. A lot of current platforms are not customized enough to address the needs of various disability profiles and do not always take into consideration factors like usability, accessibility and cognitive load. Research on the usefulness of mobile applications indicates that more comprehensive design frameworks should be developed that take into account the particular needs of the cognitive impaired persons (Huang et al., 2025).

The proposed research aims at addressing these gaps by proposing an effective adaptive learning model that will suit the needs of students with Intellectual and Developmental Disabilities. The proposed solution will be learner-oriented, based on the integration of learner profiling, adaptive content delivery and constant feedback system in order to offer a responsive and inclusive learning experience. The focus on the accessibility, customization and real-time flexibility is aimed at achieving maximum learning outcomes and inclusive learning. The key conclusions of the studies are: (i) the critical evaluation of the existing adaptive learning systems and their lack of ability to address the needs of IDD, (ii) the development of a new adaptive learning system considering the principles of cognitive and behavioral and (iii) the development of intelligent customization mechanisms and (iv) the comprehensive evaluation of the efficiency of the systems through their comparison. The research has an objective of enhancing more inclusive and better educational technologies development by this research and to assist in developing a more equitable and effective learning environment in the diverse learning students.

II. Recent Work in Adaptive Learning Systems

Inclusive education particularly among the students with the Intellectual and Developmental Disabilities (IDD) has been impacted greatly with the development of adaptive learning systems. These systems are meant to give an individual learning experience through dynamism in changing the instructional content, feedback and assessment plans. The recent literature indicates the intensified interrelation of mobile technologies, serious games, and the intelligent systems to address the multiple learning needs and improve access to learning.

One of the main tendencies in adaptive learning among students with IDD is the rise of the utilization of mobile applications and online platforms. The use of interventions based on mobile apps has been extensively studied in order to improve social skills of students with autism spectrum disorder. These applications offer interactive and real-time learning opportunities that facilitate communication, behavioral development and social interaction (Park et al., 2025). Such tools utilize multimedia features like visuals, animations and interactive situations, which are especially helpful to learners with cognitive and developmental disorders. Serious game-based learning has also become a viable strategy in aiding cognitive and process-based learning in intellectually-disabled individuals. Games-based platforms provide dynamic and immersive platforms that allow acquisition of skills through repetition, reinforcement and experiential learning. Studies show that available serious games can be of great help in enhancing learning results as they make it easier to grasp complicated ideas and offer systematic instructions (Santórum et al., 2023). Such platforms particularly come in handy in adaptive learning systems, which can be customised to the profile and progress of individual learners.

Besides process learning, the use of game-based interventions has been used to promote cognitive, emotional, and social skills among young learners. Educational games on tablets have proven to have potential in enhancing academic preparedness by activating a number of developmental spheres in tandem. Research on randomized controlled trials emphasizes that these interventions can have a

positive impact on attention, memory, and social interactions, thus contributing to the overall academic development (Rojas-Barahona et al., 2022). These results support the significance of incorporating multimodal and interactive aspects into adaptive learning systems. The other area of critical concern that is dealt with via adaptive and game based interventions is executive function development. Executive functions such as working memory, cognitive flexibility and self-regulation are critical to effective learning and day to day functioning. The systematic reviews of serious game interventions show that these tools may become significant contributors to the performance of executive functioning among neurodiverse children due to offering them structured and goal-oriented activities and immediate feedback (Rodríguez Timaná et al., 2024). Such mechanisms can be incorporated in adaptive learning frameworks to counter cognitive deficits that are usually witnessed among students with IDD. The skill of adaptive learning systems has been further extended with the advancements in artificial intelligence. Real-time video-based large language models (VideoLLMs) are also emerging technologies under investigation to support sensory impaired people. These systems allow real-time visual environmental interpretation, making it easier and more independent to learners with visual disabilities (Zhang et al., 2025). These intelligent systems can be incorporated into the adaptive learning environments and help provide multimodal support that can fill the perception and comprehension gaps.

Psychologically and behaviorally, it is critical to comprehend the cognitive and developmental nature of learners in order to create a good adaptive system. Instructional and treatment models based on the principles of diagnoses and behavior can offer a good understanding of student needs, especially those who are developmentally and mentally challenged. Extensive sources on behavioral and diagnostic models are used to highlight the need for individualized interventions to focus on cognitive and emotional facets of teach (Gill et al., 2025). These are essential in coming up with adaptive systems that are not only tech savvy but also pedagogically and psychologically enlightened. In spite of these developments, the adaptive learning systems of students with IDD are still faced with a number of challenges. Most of the existing solutions fail to integrate multiple aspects of learning and resolve individual problems, such as cognitive training or support of communication. There are no elaborate models that combine the adaptive content delivery, emotional regulation support and assistive technologies into one system. The issues of accessibility, usability and scalability are also still in question and this would further limit the usage of these technologies.

Another important limitation is the fact that the adaptive learning interventions can and must be assessed in the long-term. Despite the fact that experimental researches indicate that such systems are bright, the long run impacts of such systems on academic performance and independence are not available. Moreover, some ethical considerations such as privacy of data, inclusiveness and fairness in accessing the technology would be suitable in ensuring the implementation is responsible. To conclude, the literature shows that adaptive learning systems of students with Intellectual and Developmental Disabilities have made remarkable advancements in their development. Adopting mobile applications, serious games, AI-driven applications, and behavioral frameworks have led to more personalized and accessible learning environments. Nonetheless, the imperative of integrated, scalable and user-friendly adaptive systems is an important research gap. These issues will be critical in order to promote the inclusive education and enhance learning outcomes among the students with diverse needs.

Table 1. Review Summary of Adaptive and Assistive Learning Systems

Author(s) & Year	Focus Area	Key Findings	Limitations
Abdullah, Hafeez, N., et al. (2025)	Digital technology in behavioral support	Improves lifestyle and behavioral outcomes using digital interventions	Focuses on healthcare, not education-specific
Lima, D. T., et al. (2025)	AI for usability evaluation	Generative AI can assess usability effectively	Requires validation for real-world adaptive systems
Hu, Y., et al. (2025)	Behavioral intervention via digital programs	Improves social support and reduces problematic digital behavior	Not directly linked to learning personalization
Escriche-Escuder, A., et al. (2020)	Mobile app quality assessment	Highlights importance of usability and quality metrics in apps	Focused on health apps, not adaptive learning
Kumar, S., et al. (2024)	Blockchain in digital systems	Ensures secure data handling and privacy in digital platforms	Limited direct application to adaptive learning
Marcos Valdez, A. J., et al. (2023)	Machine learning in prediction systems	Demonstrates effectiveness of ML in decision-making systems	Domain-specific (healthcare); limited educational application

As it can be observed in Table 1, the recent literature is highly oriented towards mobile-based learning, serious games, AI-based tools, and assistive technologies to serve the needs of learners with intellectual and developmental disabilities. The majority of the researches show the enhancement of cognitive abilities, communication skills, engagement, and accessibility, which is especially achieved with the help of interactive and personalized methods. Nonetheless, one of the main shortcomings of the works is that they do not incorporate adaptive frameworks that integrate cognitive, emotional, behavioral, and technological components into one system, which implies a firm need to have more all-encompassing and comprehensive adaptive learning frameworks.

III. Theoretical Foundations and Learning Models

The adaptive learning systems of students with Intellectual and Developmental Disabilities (IDD) are based on the multidisciplinary background that incorporates the ideas of educational psychology, cognitive science, artificial intelligence, and inclusive pedagogy. The following theoretical foundations are critical in the development of systems that will not only provide personalized content, but also support the needs of learners in terms of cognitive, emotional and behavioral differences. In this section, it will discuss some of the important theory and models of learning that will be responsible in shaping an effective adaptive learning environment. Personalized learning is one of the key principles that guide adaptive learning systems and focuses on the ability to customize an educational experience to the needs of individual learners, such as abilities, preferences, learning pace, and prior knowledge. Personalized learning, in contrast to more traditional strategies that are one-size-fits-all, uses ongoing data gathering and analysis to dynamically modify the instructional strategies. In the case of students with IDD, personalization is especially important, because such learners tend to have diverse cognitive profiles, and need differentiated instruction. Adaptive systems exploit the learner models to record the performance history, pattern

of behaviour and level of engagement to build a tailored learning journey.

The constructivist learning theory is an important contribution to the adaptive learning design, viewed through the lens of cognition. Constructivism is a theory that argues that learners are actively involved in building knowledge as a result of their interaction with the world and not passively receiving information. In the students with IDD, this means that interactive, experiential and contextual based learning activities are necessary to facilitate learning through practice and reinforcement. Adaptive systems adopt constructivist principles in that they include simulating, problem-solving activities and interactive materials that enable the learners to learn at their pace. The other relevant model is that of behaviorist learning theory that emphasizes on observable behaviors and how reinforcement contributes to learning. Behaviorist methods are especially applicable to the developmentally disabled learner because, through the use of reinforcers, it is possible to enhance the attention and motivation as well as improvement of tasks. Other common behaviorist aspects of adaptive learning systems include instant feedback, rewards and progress tracking to reinforce what is desired to be learned. Badges, points, and levels are typical gamification techniques that help to maintain engagement and promote regular involvement.

Besides cognitive and behavioral theories, the social learning theory emphasizes the role of interaction, observation and collaboration in learning. Students with IDD might experience difficulties when interacting with peers and it is important to come up with systems that facilitate interaction and peer communication. Adaptive learning systems also have the ability to utilize collaborative tasks, guided communication and social simulation to support communication skills and provide a feeling of belonging. One of the widely known guidelines in inclusive education is the Universal Design of Learning (UDL), which offers tips on the development of flexible-learning environments that embrace diverse learners. UDL relies on three principles: multiple means of representation, multiple means of engagement and multiple means of action and expression. Adaptive learning systems that follow the principles of UDL provide content in multiple formats (text, audio, video), alternative methods of interaction between the learner and material and multiple assessment opportunities. Such adaptability is important to meet the diverse needs of students with IDD.

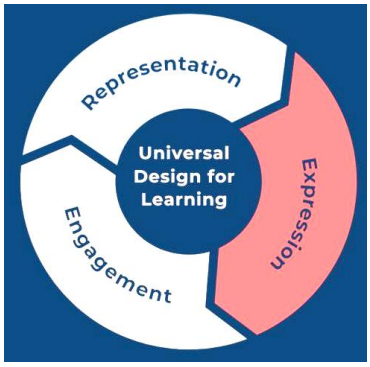

Figure 1. Universal Design for Learning Principles

Figure 1 depicts Universal Design for Learning Principles that is applied by Universal Design for Learning (UDL) framework. It is a learner-focused framework that guarantees inclusive and flexible learning as it focuses on different learning needs using three main principles. The learner is at the center of the model which is surrounded by three interconnected parts Multiple Means of Representation, that focuses on the presentation of information in a variety of forms (text, audio, and visuals) to support different comprehension skills; Multiple Means of Engagement, that aims to motivate learners to achieve their comprehension by engaging them in a variety of interactive, personalized, and interest-driven activities; and Multiple Me Collectively, all these elements create a unified system, which fosters the accessibility, engagement, and flexibility of learning environments, making education more efficient in students with IntellectUAL and Developmental Disabilities. The other important feature of adaptive learning systems is the inclusion of cognitive load theory that focuses on the control of information processing requirements on learners. The working memory capacity of students with IDD is often limited: it is of significance to develop instructional materials that are as easy as possible to memorize. This is met by adaptive systems by breaking down

complex information into small and manageable bits, as well as giving step-by-step instructions and changing the level of difficulty, according to the performance of the learners. The adaptive systems can also be made more effective by the integration of the models of affective computing and emotional learning. Affective conditions like anxiety, frustration and motivation have a great impact on the learning process especially to the students with developmental disabilities. Adaptive systems may include the sensors, user feedback and behavioral indicators to identify emotional states and modify the content. As an illustration, the system can make tasks easier or offer more assistance when a learner shows signs of being frustrated to keep the learner engaged.

Over the past few years, the adaptive learning systems have been dominated by learning models that are based on artificial intelligence. Machine learning algorithms can be used to build predictive models that can be used to predict the needs of the learners and deliver content in the most optimal manner. Reinforcement learning, recommendation systems and natural language processing are some of the techniques used to enable the systems to offer personalized feedback, adaptive assessments as well as intelligent tutoring support (More et al., 2025). This is because these models increase the scalability and efficiency of the adaptive learning systems, which can be applicable across a wide range of learning situations. Moreover, interactive learning models that incorporate the use of technologies like Augmentative and Alternative Communication (AAC), voice interfaces, and multimodal interaction are very instrumental in assisting learners with IDD. These models make sure that learners having communication, or motor challenges can easily interact with the system and thus make it more accessible and inclusive. Even with these theoretical frameworks available, one of the biggest problems is the integration of these different frameworks to come up with a single adaptive learning model. A large number of the current systems are oriented towards single facets of a learner, like cognitive performance or behavioral reinforcement, without targeting the comprehensive needs of a learner. Increased demand is on hybrid models that are used to integrate cognitive, behavioral, social and technological approaches to produce complete learning environments.

IV. Proposed Adaptive Learning Framework

The proposed adaptive learning model will target to offer a non-discriminatory, intelligent and personalized learning experience to Intellectual and Developmental Disabilities (IDD) learners. Unlike conventional educational systems, the model is an amalgamation of artificial intelligence (AI), supportive technologies, and inclusive pedagogical practices to address the diverse cognitive, behavioral, and communication needs of learners. The system is developed following a modular and a layered architecture which grants it flexibility, scalability and incessant adaptation owing to real time interactions of the learners.

- **System Architecture and Design Components**

The system architecture has been structured in such a way that it is structured into a number of interrelating layers with each layer consisting of various functionalities but data flows smoothly in all the layers of the structure. It consists of its core components namely the data acquisition layer, learner profiling module, adaptive engine, content delivery system, assistive support module and feedback and assessment module. The adaptive intelligence engine is the main component of the architecture and is the decision maker. This component is a combination of machine learning algorithms, rule-based system, and recommendation model to process learner data and give individual learning paths. In the environment of this core there are support modules that aid in proper interaction, monitoring of access and performance. It is structured based on Universal Design of Learning (UDL) principles, which help to ensure that all learners of various abilities can receive content in various formats, can interact using interactive means and can show their knowledge in various ways. The modular nature of the design also enables it to be easily integrated with existing Learning Management Systems (LMS), mobile applications and assistive devices and, therefore, may be easily deployed in real-world settings, such as inclusive classrooms.

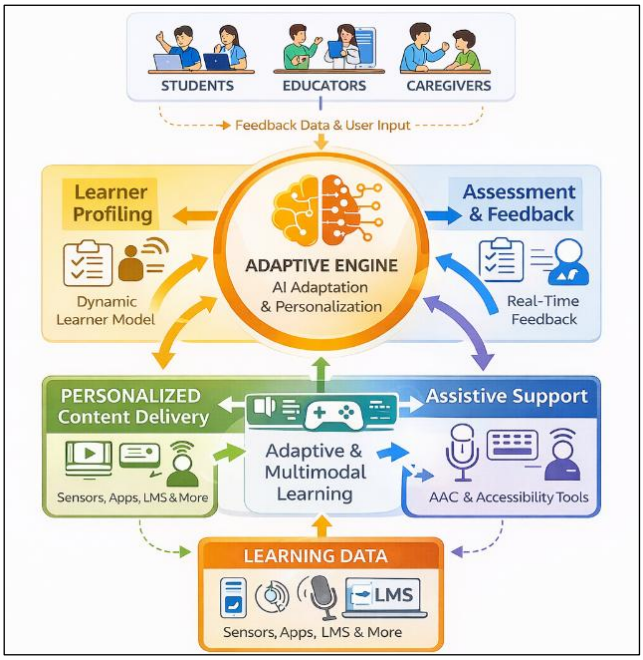

Figure 2. Adaptive Learning System Architecture

Figure 2 is an illustration of a proposed adaptive learning model that is aimed at offering a flexible, inclusive and smart learning experience to Intellectual and Developmental Disabilities (IDD) students. The model incorporates the use of artificial intelligence, assistive technology, and inclusive pedagogical concepts to meet the cognitive, emotional, and behavioral learning needs. It also has a modular and layered architecture and therefore it is scalable, flexible and can adapt to real time.

The framework has the learner profiling module at the center, which gathers and interprets the information pertaining to the learner skills, preferences, performance and habitual patterns of behavior. The module is based on AI-powered analytics to develop dynamic learner models that constantly change depending on user interaction. The profiles are useful in personalizing the learning needs and instructional plans. The second layer is the data acquisition layer, which receives the input of various sources like learning management systems, mobile applications, sensors and user interactions. This module is in line with the principles of Universal Design of Learning (UDL) as it provides multiple ways of representation, engagement, and expression. The aspects of gamification (rewards, badges, progress tracking) are combined to make the game more motivating and engaging. Assistive support module consists of components like Augmentative and Alternative Communication (AAC), voice assistants and accessibility like text to speech and speech to text. These devices allow communication and motor-challenged learners to efficiently interact with the system, thus enhancing the accessibility and inclusiveness. The assessment and feedback module is a continuous evaluation of the performance of the learners in terms of quizzes, activities and behavioural analysis. It offers a real-time and personalized feedback and recommendations to learners and educators. This module facilitates continuous improvement through identifying the learning gaps and modifying the instructional approaches based on the gaps. Lastly, the application/user interface layer takes care of a smooth interaction between the system and the learner. Its interface is made easy, intuitive, and user friendly, reducing the cognitive load and increasing the usability. Dashboards can also be available to educators and caregivers to track the progress of learners and assist them further.

- **Data Acquisition and Learner Profiling**

The success of an adaptive learning system greatly hinges on its capacity to precisely comprehend and model the learner. The data acquisition layer will be in charge of gathering explicit and implicit data, which are obtained in different sources. Explicit data comprises of the user inputs like quiz answers, assignments and preferences whereas implicit data comprises of the interaction patterns, time spent on the task, incidence of errors, and level of engagement. State-of-the-art data collection systems can also integrate sensor-driven data, to gauge attention, emotional conditions, and cognitive load, by eye-tracking, voice recognition, or behavioral cues. These inputs come in handy especially among learners with IDD who have more insight on learning challenges and challenges of engagement. The processed data is formed to produce a dynamic learner profile, which comprises several dimensions (including Cognitive abilities (memory, comprehension, processing speed), Learning preferences (visual, auditory, kinesthetic), Behavioral traits (attention span, motivation, engagement patterns) and Communication abilities and assistive needs). These profiles are constantly changed by machine learning models hence the system is able to adjust with changes in the performance of the learners as time goes by. This dynamic profiling allows the system to provide very personalized learning experiences, which are individualized.

- **Adaptive Content Delivery Mechanisms**

The content delivery module takes care of the delivery of the learning materials in such a way that it meets the profile of the learner. In this module, adaptive content sequencing as well as multimodal presentation strategies are used to promote comprehension and engagement. The content is presented in many forms; text, audio, video, animation and interactive simulations. In particular, students with reading challenges can be provided with audio-based materials, while those with attention disorders can be offered to learn on the basis of short, game-based learning resources. The system also adapts the level of difficulty, pacing and content complexity of the material, according to real time performance data. Adaptive technologies are Content recommendation systems to propose the kind of learning materials to be used, Dynamic difficulty adjustment in relation to learners performance, Gamification, badges, rewards and tracking of progress as well as Scenario-based and experiential learning modules to enhance practical learning. The system also incorporates assistive technologies, including text-to-speech, speech-to-text, visual aids and Augmentative and Alternative Communication (AAC) technologies. These characteristics will make the learning process more inclusive, and the learners with communication or motor disabilities can access it.

- **Feedback, Assessment, and Personalization Engine**

The feedback and assessment module is important to assess the development of learners and inform the process of adapting. This framework uses continuous and formative assessment methods as opposed to periodic testing, which is the case with the traditional assessment systems. The system assesses the performance of the learner based on quizzes, interactive activities, behavioral and engagement indicators. It creates immediate feedback, which is specific to the level of cognition and mood of the learner. An example is that when a learner finds a concept difficult, then the system can give simplified explanations, more examples or alternative learning paths. The adaptive system includes the personalization engine which employs the data on assessment to narrow learning pathways. It includes Predictive analytics to predict learner challenges, Content and activities recommendation algorithms, Reinforcement learning methods to streamline the learning plan and Emotional adaptation systems to adapt content according to the learner motivation and stress. This teamwork strategy will make sure that the human aspect supplements the technological adjustments. Moreover, the feedback loop establishes a closed-cycle system of learning, in which continuous data gathering and analysis, adaptation and reassessment takes place. Such a process can improve the effectiveness of learning and guarantee the long-term increase in the academic performance and skills improvement.

V. Implementation and Methodology

The application of the suggested adaptive learning model is aimed at creating a scalable, smart, and user-friendly system that is adaptable to the needs of Intellectual and Developmental Disabilities (IDD) students. This section presents the tools, technologies, system integration process, experimental setting, evaluation measures and ethical issues of implementing the framework in actual education setting.

To make the proposed system successful, the combination of the latest software technologies, artificial intelligence methods, and assistance tools are used. Python and JavaScript programming languages are used to create the back end of the system, which can be integrated with machine learning and deployed using web resource. Such frameworks as TensorFlow, PyTorch, or Scikit-learn are used to create predictive models and adaptive algorithms. To develop the front-end interface, there are technologies including HTML5, CSS3 and React.js, which are applied to develop responsive, interactive and accessible user interfaces. Cross-platform systems such as Flutter or React Native are used to ensure mobile compatibility, with learners being able to use the system on both tablets and smartphones.

It is built based on the modular architecture that enables the development of each part separately and integrates all the parts. The implementation is based on three tier architecture which includes:

1. Presentation Layer- Student, educator and caregiver interface.

2. Application Layer: Adaptive engine, learner profiling and decision making modules.

3. Data Layer - learner data and system analytics storage and management.

All modules are connected via RESTful APIs, which means that data exchanges and interoperability of the systems will be seamless. The adaptive engine will be combined with machine learning models that will analyze the information about learners and produce personalized recommendations. The system has the capability of synchronizing data in real time, thus facilitating real time monitoring of the interaction between learners. Connection to assistive devices and external services guarantees that the system is able to be efficiently used in a variety of learning situations, such as classroom, remote learning, and rehabilitation facilities.

An experimental study is used to assess the effectiveness of the proposed framework that was performed among students with Intellectual and Developmental Disabilities. The research is planned as a controlled experimental one: the participants will be classified into two groups:

- Control Group - Uses non-adaptive or traditional learning systems.
- Experimental Group- Uses the proposed adaptive learning system.

The experiment is carried out within a specific time, where learners are exposed to learning material, which meets their capabilities. There are several parameters that data is gathered on such as performance in learning, degree of engagement, completion rate of tasks and satisfaction of users. The experimental design consists of Pre-assessment to assess the level of knowledge before the use of the system, Continuous monitoring during the use of the system and Post-assessment to gauge the learning improvement. Qualitative feedback on the usability and accessibility of the system and the effectiveness of the system is also given by educators and caregivers.

The effectiveness of the suggested adaptive learning system is assessed with the help of a complex set of quantitative and qualitative indicators to reflect the academic performance and user experience. The performance of learning is measured using the indicators of accuracy, test scores, and increase in conceptual understanding and task completion rates, which are all indicators of the efficiency of the system in improving the acquisition of knowledge. Besides this, to determine learner engagement, time spent on learning activities, frequency of system interaction and active involvement in tasks are also parameters used to give an insight into the level of motivation and involvement. Personalization

effectiveness is measured by looking at the level to which the system adapts the content to individual needs of learners and how much the level of learning errors reduces with time. The other areas of the evaluation that are vital are usability and accessibility which are tested on the basis of ease of navigation, simplicity of interface and compatibility with the assistive technologies, to ensure that the system is inclusive and easy to navigate among the students with Intellectual and Developmental Disabilities. Also, behavioral and emotional indicators, such as a reduction of the level of frustration, expansion of motivation and attention range are assessed to understand the impact of the system on the well-being of learners. They are presented visually using graphical analysis such as bar charts, line graphs and radar charts to provide an easy and comparative analysis of the system performance. These visualizations will be helpful in comparing the outcomes of the proposed adaptive learning system to the existing learning process and showing the positive shifts in the performance, engagement, and learning performance in general.

The application and the process of the suggested adaptive learning framework illustrate a holistic approach towards creating an intelligent, accessible, and scalable framework to support the students with Intellectual and Developmental Disabilities. Innovative technologies, effective assessment methods and ethical consideration can be applied to the framework to help make it successful in the practical learning environment. The results of this implementation would have been a very reliable ground to support the effectiveness of adaptive learning systems in ensuring inclusive learning.

VI. Comparative Analysis with Tables and Graphs

A comparative analysis of the traditional learning model with the proposed adaptive learning system was done to determine the effectiveness of the proposed adaptive learning framework. The comparison has been made on key performance indicators such as learning outcomes, engagement, personalization, usability and improvement of behaviors. The findings are a clear indication of the excellence of the adaptive approach in all dimensions.

Table 2. Performance Comparison Between Traditional and Adaptive Learning Systems

Metric	**Traditional Learning System**	**Adaptive Learning System**
Learning Accuracy	60% – 70%	85% – 92%
Concept Understanding	Moderate	High
Task Completion Rate	65%	90%
Engagement Level	Low to Moderate	High
Time Spent on Learning	Limited	Increased
Personalization	Not Available	Fully Adaptive
Error Reduction	Slow	Rapid
Usability	Moderate	High
Accessibility Support	Limited	Advanced (Assistive Tools)
Motivation & Attention	Low	High

Table 2 indicates that the adaptive learning system performs much better than the traditional learning approach in all the important metrics. It has been shown to be more accurate in learning, better in comprehending concepts and faster in completing tasks because of the personalization of the content and the real-time adjustability. The level of engagement and time spent learning is also

significantly better, meaning that there is more student engagement and interest in learning. The adaptive system also offers high-level personalisation and quicker error-reduction, and is much easier to use with robust accessibility guidelines, which are mostly missing in conventional approaches. On the whole, the table shows that adaptive learning establishes an effective, inclusive, and learner-centered learning setting.Figure 3 measures (accuracy, engagement, task completion) reveal that the adaptive learning system has a great improvement in performance.

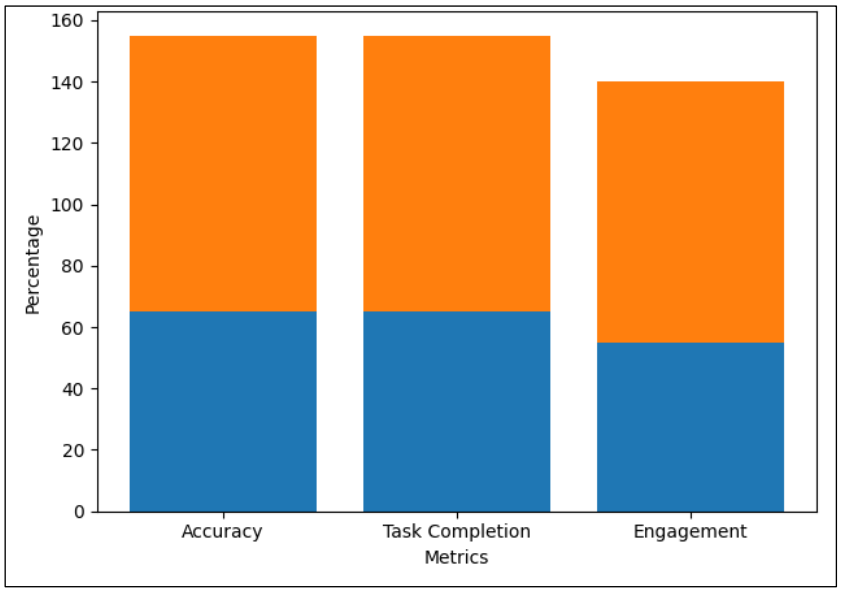

Figure 3 . Performance Comparison

Figure 3 metrics (accuracy, engagement, task completion) shows a significant increase in performance for the adaptive learning system. To illustrate, the accuracy increases by about 65 per cent with the conventional methods to more than 90 per cent with the adaptive system. The upward trends are also similar in engagement and task completion.

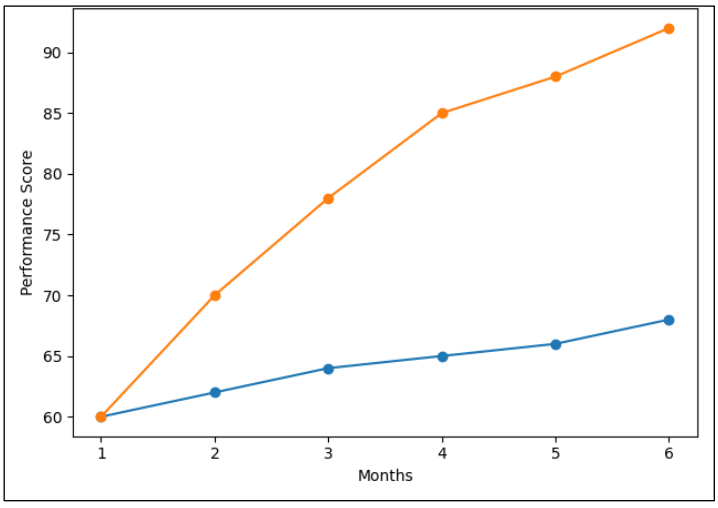

Figure 4. Learning Performance Over Time

The performance of students in a 6-month time shows in Figure 4 shows Traditional system: gradual improvement (60 → 68) and Adaptive system: rapid and consistent growth (60 → 90+). This means that the adaptive system enables the quicker learning process and long-lasting learning.

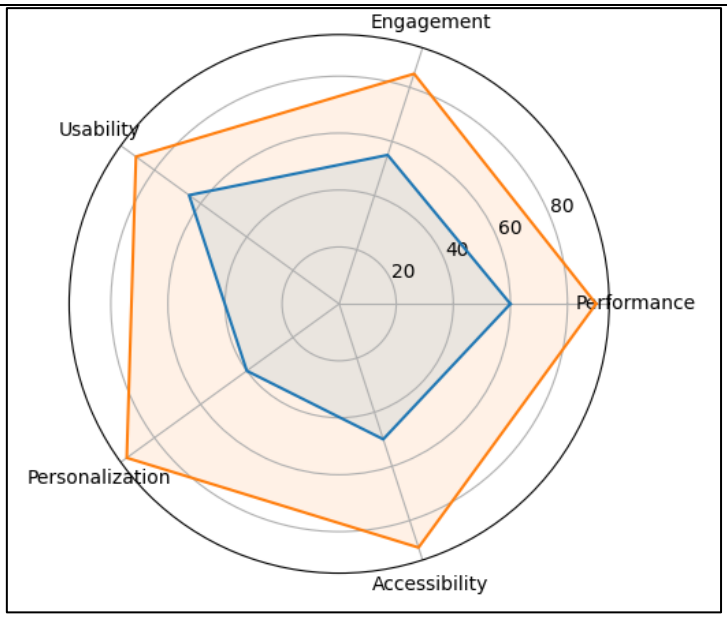

Figure 5. Multi-Dimensional Comparison

When comparing various parameters (performance, engagement, usability, personalization, accessibility) in figure 5, it can be seen that the adaptive system comprises a larger and more balanced polygon, which means its performance in all aspects is better compared to the traditional system, which is less covered.

The comparative analysis has shown that the proposed adaptive learning system is far superior to the conventional learning systems. Learning accuracy and understanding of the concept can be noted as the most significant improvement, which can be explained by the personalized content delivery and real-time adaptation. This is because the system permits the learners to be challenged but not overwhelmed by the difficulty level and vice versa. The effectiveness of the system is also supported by engagement measures. The interactive and gamification features result in higher engagement and increased learning time. This continual involvement leads to better learning results. The second advantage which is also critical and significant is that, the system is customized and not in the case of the traditional models. The adaptive system offers new learning paths to its learners by continually analyzing their data, leading to a reduction in errors and enhanced retention. In addition, there will also be an incorporation of the assistive technologies resulting in an increased accessibility and consequently, the system will also be more accommodative to students with diverse needs. Other spheres of behavior such as motivational levels and frustration levels have been affected by the system too. The aspects are very important in the success of long term learning particularly in students with Intellectual and Developmental Disabilities.

VII. Conclusion and Future Directions

The proposed adaptive learning model is a giant innovation as far as planning and implementing inclusive learning technologies to students with Intellectual and Developmental Disabilities (IDD) are concerned. The system is meant to fulfill the diverse cognitive, behavioral and communication requirements of learners through the integration of the concepts of artificial intelligence, assistive technologies and learner-centered pedagogy. The results and the comparative study show that the adaptive learning method does not only enhance the academic performance but also enhances the engagement, motivation and generally the learning experience. The dynamic nature of the system in adjusting the content, in giving real-time feedback, and accessibility features guarantees that learners obtain personalized and meaningful support in education.

The fact that the proposed framework is developed in a holistic way and combines numerous aspects such as profiling of learners, adaptive content

delivery, and assistive support, and continuous evaluation into one framework is one of the strongest points of the proposed framework. This integration assists the system to take a step further in comparison to the traditional models of learning, which only look at learning as academic outcomes but rather as emotional and behavioral issues which influence learning. The introduction of the Universal Design of Learning (UDL) also plays a role in the framework by providing flexibility, accessibility and inclusivity of learners with varying abilities. The proposed system is effective but has its limitations that need to be taken into consideration in the future work. It will be practically applied only in the case of the availability of digital infrastructure and assistive technologies that not all educational facilities have. Also, adaptive engine accuracy is based on the quality and quantity of learner data, which might not be similar among users. It also needs extensive validation in real world by long term research of a large scale of learners to ascertain scalability and sustainability of the system. Future research directions may aim at increasing the functions of the adaptive learning framework by adding more advanced technologies like deep learning, emotion recognition systems, and in-world learning with virtual and augmented reality. Personalization can be further enhanced through the incorporated use of real time affective computing in order to tailor the content according to the emotional state of the learners. Moreover, multilingual and culturally adaptive systems can be developed, increasing the framework application in a variety of educational settings.

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